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(58) Field of search
C7A

(71) Applicants

Johnson Matthey & Co
Limited
43 Hatton Garden
London EC1N 8EE
England
James Edward Restall
18 Alphington Avenue
Frimley
Camberley
Surrey GU16 5LB

(72) Inventors

ABin Sidney Pratt
Duncan Roy Coupland

(74) Agents

Withers & Rogers

(54) Nickel-based high-tempera-
ture alloy containing platinum
group metal

(57) The invention relates to nickel-
chromium based gamma prime al-
loys consisting in percentages by
weight (apart from impurities) of

aluminium (4 to 13.5%), chromium
(trace to 6%), one or more metals
of the platinum group (trace to
20% total) and balance nickel.

Alloys according to the invention
possess good corrosion resistance
at elevated temperatures in excess
of 900°C. They may also contain
up to 5% Hf, 6% Ti, 12% Ta, 6%
Nb, 0.15% C, 0.1% B, 10% Co,
14% Mo, 14% W, 1.75% Zr,
0.25% Si and/or 3% of one or
more of Sc, Y, R.E. metals. Those
elements listed from Nb onward
may be present wholly or partially
as their oxides.

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FIG.1.

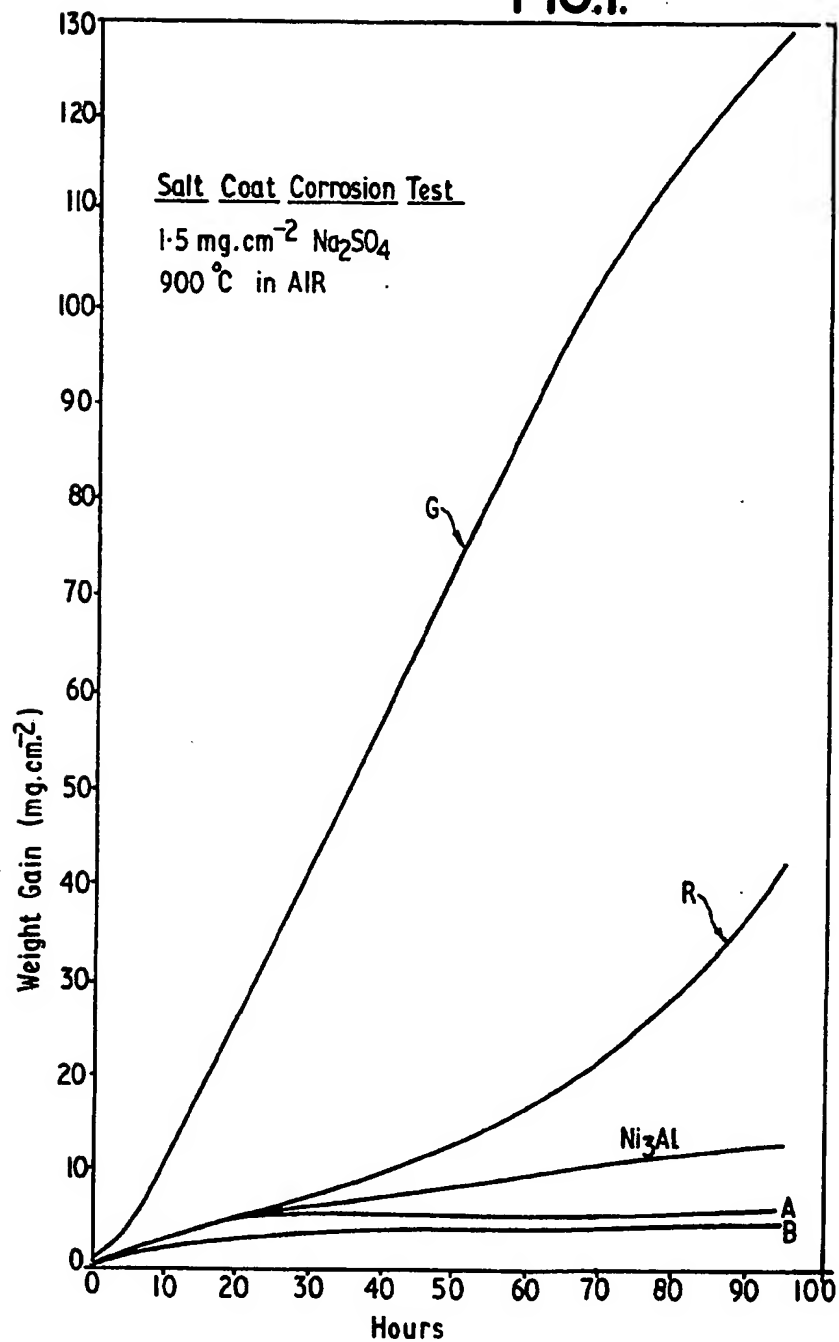


FIG.2.

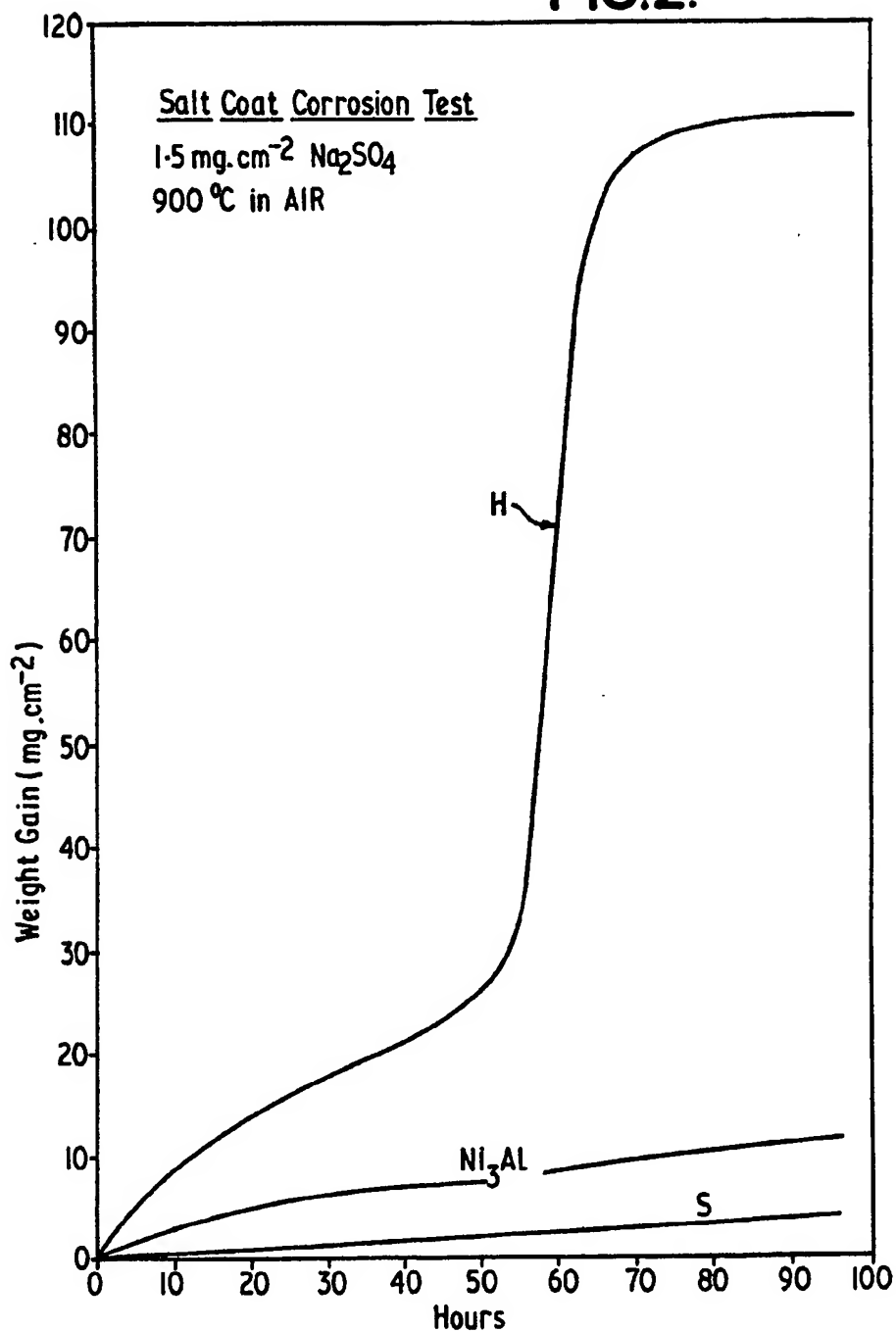
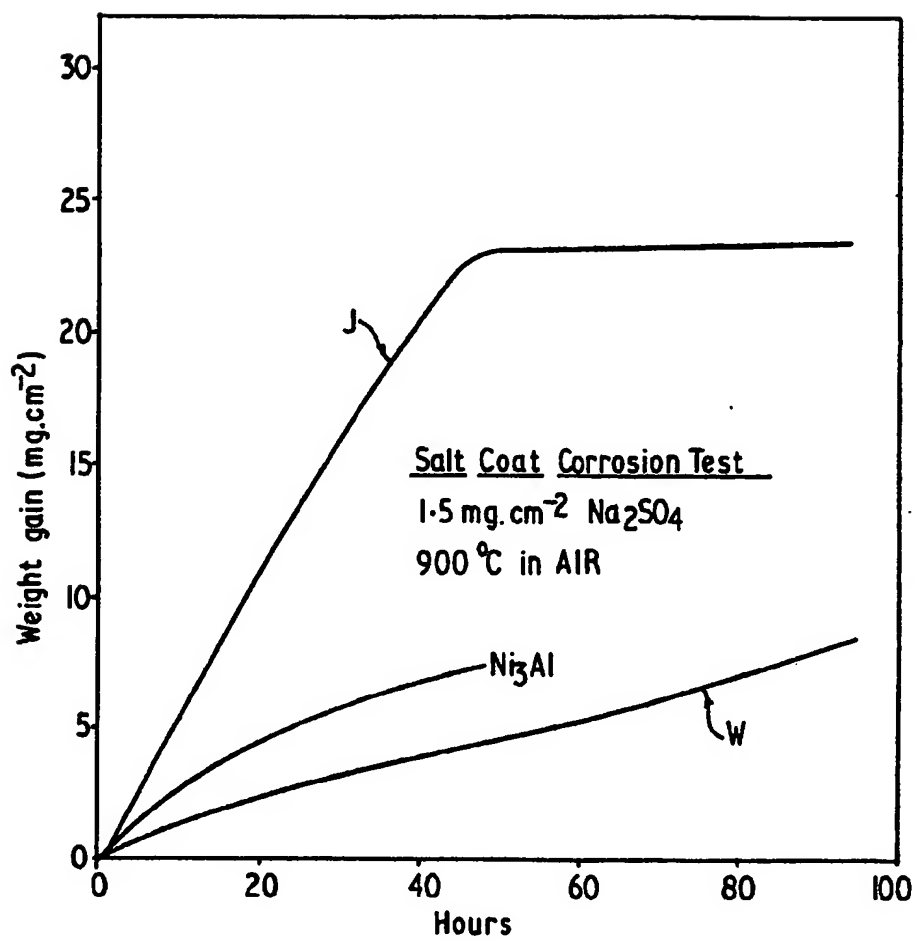


FIG.3.



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FIG.4.

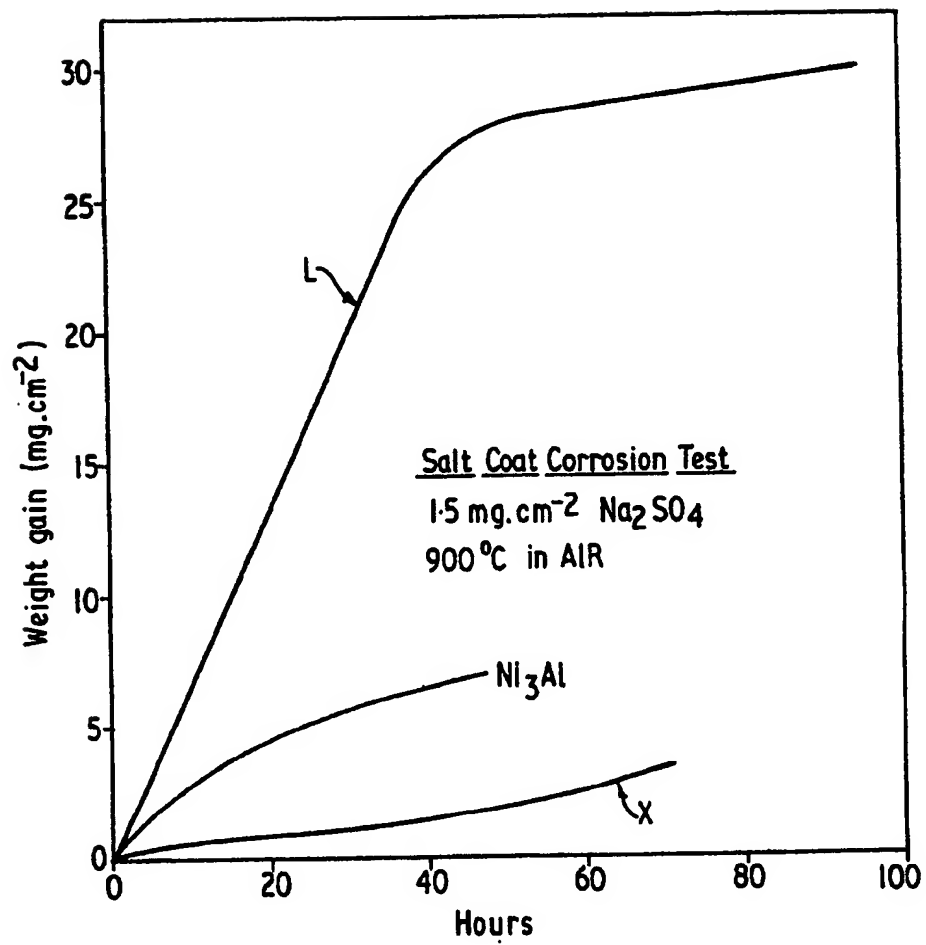


FIG.5.

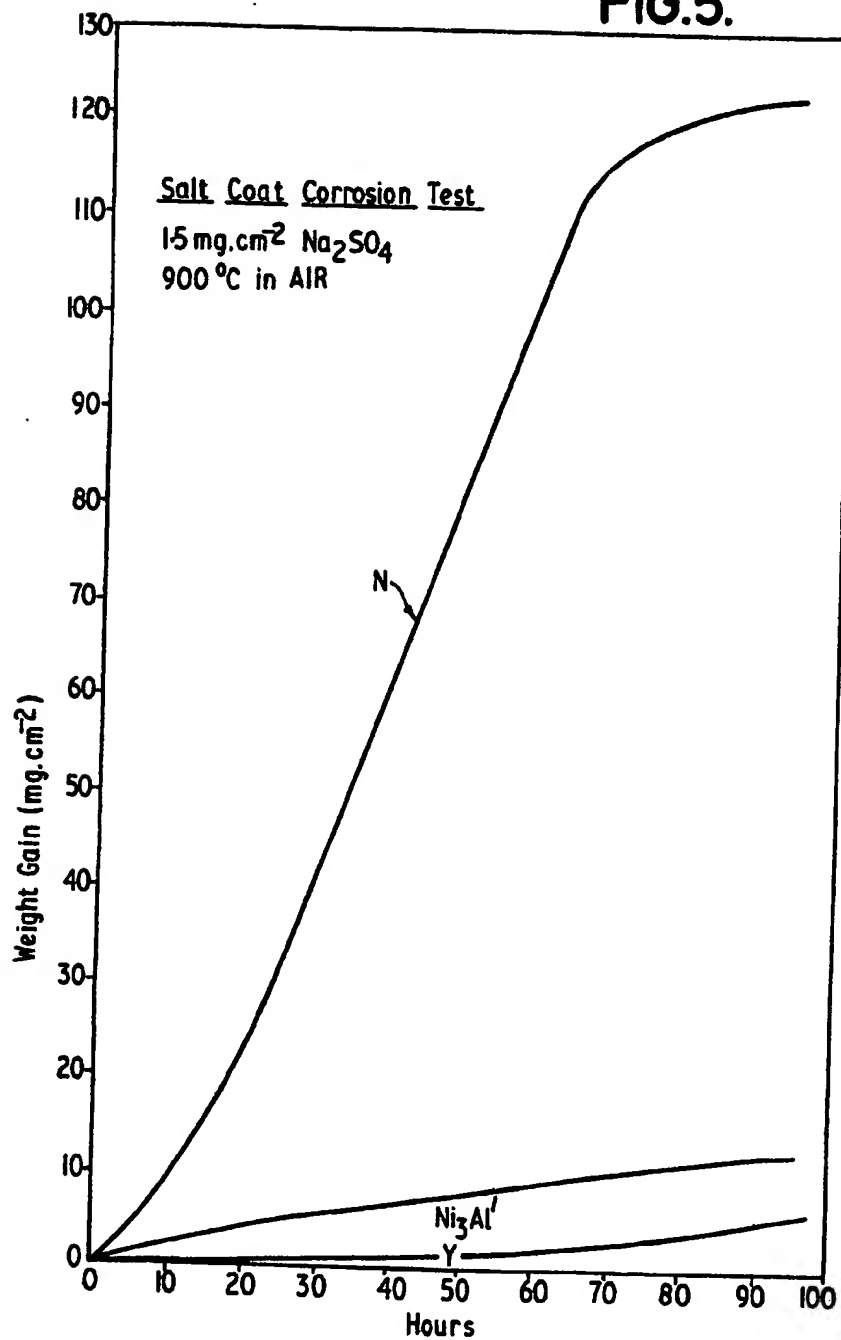
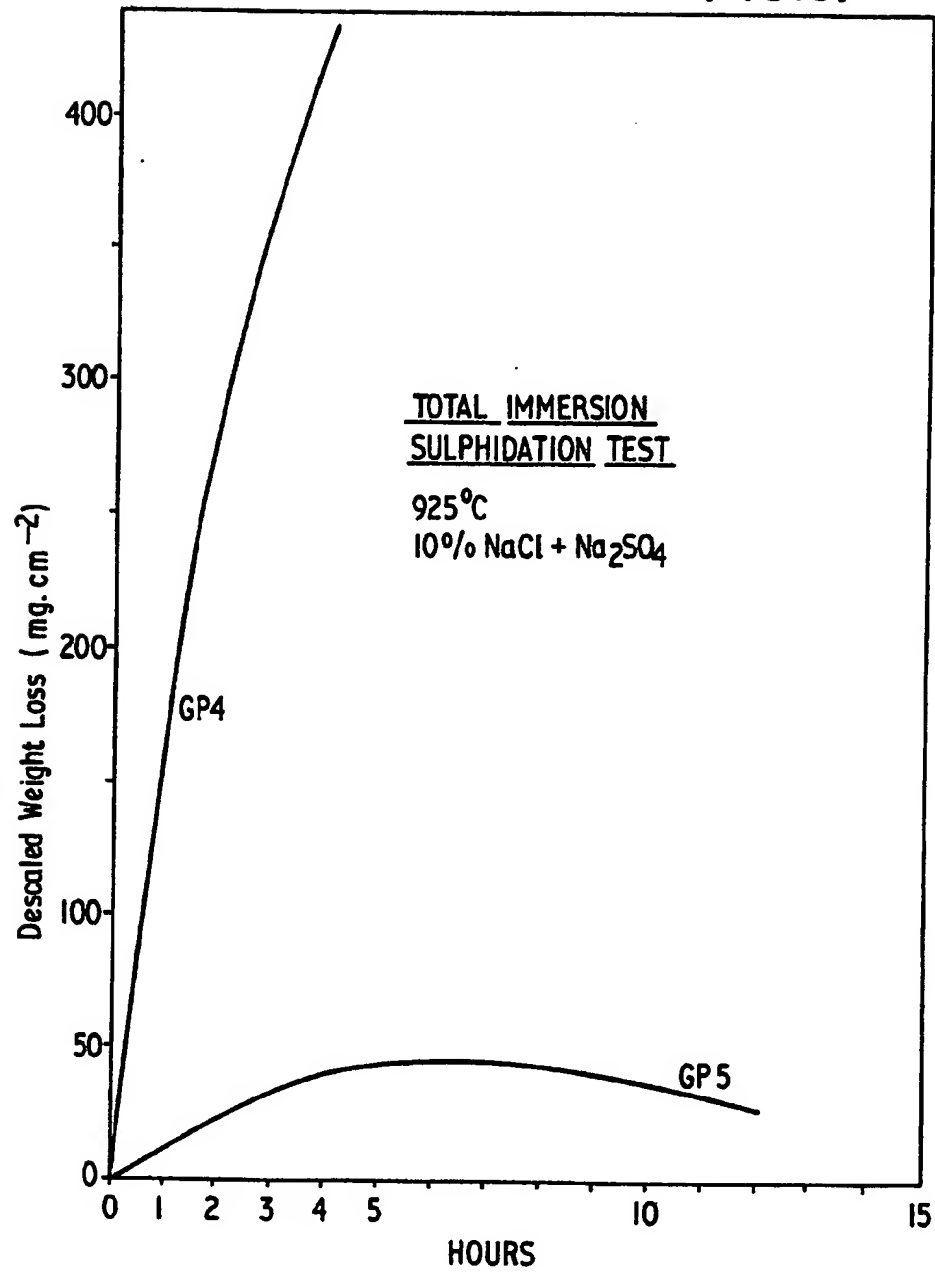
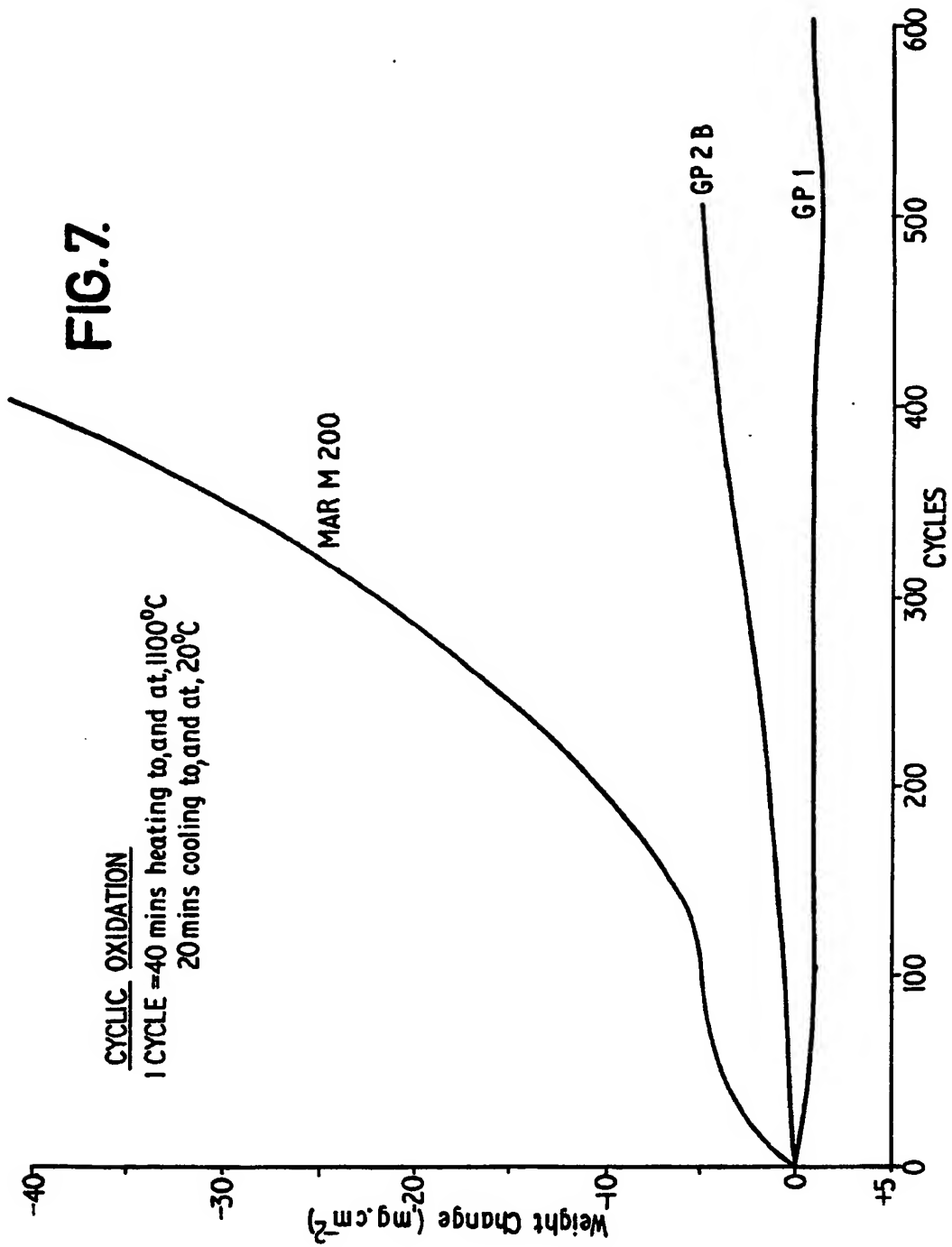


FIG.6.





SPECIFICATION

Platinum group metal containing alloy

- 5 This invention relates to platinum group metal-containing alloys. In particular, the invention relates to nickel-chromium based gamma-prime alloys containing platinum group metal. 5
- In our British Patent No. 1520630, we describe and claim certain nickel- and cobalt-based alloys containing platinum group metal and consisting essentially of (a) 40–78% Ni and/or Co, (b) trace–25% Cr, (c) trace–15% of platinum group metal and (d) trace–13% Al and/or Ti.
- 10 Such alloys possess a remarkably high temperature capability particularly in respect of their strength and creep resistance and are eminently suitable for such purposes as the fabrication of parts for use in the glass industry and in that part of the aero-engine industry concerned with jet engines and gas turbines. 10
- We believe that the metallurgical structure of alloys according to said British Patent No. 1520630 comprises a matrix of the nickel-chromium gamma phase including a minor proportion of the platinum group metal present, together with up to about 65% by weight of the gamma-prime phase which comprises principally tri-nickel aluminide (Ni_3Al) substituted with platinum group metal, chromium and other alloying ingredients. Most—this is to say, probably in excess of 90%—of the platinum group metal is present in the gamma-prime phase and, we believe, is substituted predominantly for the aluminium constituent of said phase. 15
- 20 Although Ni_3Al does not itself possess useful physical properties for rigorous applications such as those described above, it is nevertheless generally believed to be the presence of Ni_3Al —that is to say, a gamma-prime phase, particularly such a phase also containing platinum group metal—in association with one or more other phases, which contributes to the said high temperature capability. It is also believed that alloys comprising a matrix of gamma-prime show enhanced temperature capability compared with alloys comprising a matrix of gamma inter-spersed with a precipitate of gamma-prime, but hitherto such alloys have tended to have relatively poor corrosion resistance, particularly at elevated temperatures. It is therefore an object of the present invention to provide a novel alloy which overcomes this disadvantage. 20
- 25 According to a first aspect of the invention, we provide a nickel- and chromium-based alloy consisting in percentages by weight and apart from impurities, of aluminium (4–13.5%), chromium (trace–6%), one or more metals of the platinum group (trace–20% total), balance nickel. 25
- By “metals of the platinum group” we mean platinum, rhodium, iridium, ruthenium, palladium and osmium. Of these, we particularly prefer to use one or more of platinum, rhodium and ruthenium. 35
- According to a second aspect of the invention, we provide an alloy according to the first aspect and also containing hafnium (trace–5%) and/or titanium (trace–6%) and/or tantalum (trace–12%).
- 40 According to a third aspect of the invention, we provide an alloy according to either the first or second aspects and further containing from a trace to the weight specified of one or more of the following metals: 40
- | | | |
|--|-------|----|
| niobium | 6% | |
| 45 carbon | 0.15% | 45 |
| boron | 0.1% | |
| cobalt | 10% | |
| molybdenum | 14% | |
| tungsten | 14% | |
| 50 zirconium | 1.75% | 50 |
| Scandium, yttrium or oxides thereof and/or rare earth metals or oxides | 3% | |
| 55 silicon | 0.25% | 55 |
| magnesium | 1% | |
| iron | 10% | |
| manganese | 0.25% | |
| vanadium | 2% | |
| 60 | | 60 |
- It is to be understood that, in addition to the oxides of scandium, yttrium and the rare earths referred to above, other ingredients, for example Zr, of alloys according to the invention may be present at least partially as their oxides. The said oxides may either be added as such to the other alloying ingredients or may be formed *in situ* under the conditions of alloy formation.
- 65 One particular alloy according to the invention has the composition, in percentages by weight: 65

Al 7.3%, Ti 0.8%, Co 6.5%, Nb 0.99%, Mo 1.0%, Ta 10.5%, Cr 2%, W 2%, C 0.05%, B 0.01%, Zr 0.07%, Pt 7.5% and balance nickel.

- Alloys according to the invention comprise a matrix of dendritic gamma-prime phase infilled with gamma and or beta, alpha, borides, carbides and so on indentrictically, the precise structure depending on the aluminium content. We believe that the platinum group metal occurs at least in the gamme-prime and NiAl beta phases. The alloys can be produced by standard vacuum melting and casting techniques or by mechanical alloying, for example. A preferred method comprises uni-directional solidification, which enhances mechanical strength in the direction of solidification.
- 10 We have found that alloys according to the invention have a temperature capability of up to about 1100°C with respect to strength and oxidation resistance, which is superior to most conventional Ni-base superalloys and approximately comparable to prior art alloys comprising a matrix of gamma-prime. Alloys according to the invention also show enhanced hot corrosion resistance compared with most prior art conventional superalloys and also prior art gamma-prime matrix alloys.
- 15 The following Table 1 gives examples of alloys according to the invention together with various prior art alloys. The figures for composition are based on weight added and it is to be understood that analysis of any given alloy would probably yield figures marginally different from those quoted.

TABLE 1.
Alloy Composition (wt. %).

| | Pt | Ni | Al | Ti | Cr | Co | W | Mo | Ta | Nb | Others |
|------|------|----|-------|------|------|------|------|------|------|------|------------------------------|
| K | | | 13.28 | | | | | | | | |
| G | | | 10.4 | 4.6 | | | | | | | |
| A | 16.6 | | 9.2 | 4.1 | | | | | | | |
| B | 16.2 | | 6.8 | 4.0 | | | | | | | |
| R | 8.73 | | 8.69 | 4.28 | | | | | | | |
| H | | | 9.7 | 3.4 | 3.7 | | | | | | |
| S | 8.7 | | 8.05 | 3.2 | 3.45 | | | | | | |
| J | | | 7.1 | 3.2 | 3.4 | 7.8 | 8.1 | | | 2.0 | |
| W | 7.96 | | 5.74 | 2.94 | 3.2 | 7.2 | 7.52 | | | 1.95 | |
| GP4 | | | 6.8 | 3.9 | 2.6 | 6.52 | 8.1 | | | 4.1 | |
| GP5 | 15.2 | | 4.8 | 3.7 | 2.7 | 7.5 | 7.9 | | | 4.1 | |
| L | | | 7.2 | 3.2 | 3.5 | 7.8 | | 3.2 | 6.0 | | |
| X | 8.08 | | 5.28 | 2.98 | 3.23 | 7.32 | | 2.97 | 5.62 | | |
| N | | | 7.1 | 3.1 | 3.4 | 7.7 | 5.6 | 1.7 | 3.2 | | |
| Y | 7.98 | | 5.73 | 2.94 | 3.19 | 7.24 | 5.26 | 1.56 | 2.96 | | |
| GP1 | 7.5 | | 7.3 | 0.8 | 2 | 6.5 | 2 | 1.0 | 10.5 | .99 | C-.05 B-.01 Zr-.07 |
| GP2A | | | 7.3 | 1.0 | 2.5 | 7.5 | 2 | 1.5 | 7.0 | 2.5 | C-.08 B-.02 Zr-.05 Hf-1.5 |
| GP2B | 7.0 | | 6.9 | 0.9 | 2.2 | 7.5 | 1.8 | 1.5 | 6.0 | 2.2 | C-.08 B-.02 Zr-.05 Hf-1.5 |
| GP3 | 4.6 | | 10.0 | 1.2 | 2.5 | 7.2 | 2.0 | 1.3 | 5.5 | 2.5 | C-.08 B-.02 Zr-.05 |
| GPY | 7.5 | | 7.05 | 0.8 | 2.0 | 7.0 | 2.0 | 1.0 | 10.0 | 1.0 | C-.05 B-.01 Zr-.07 Y-.3 |

The following Table 2 and Figs. 1-5 show results for various alloys according to the invention compared with various prior art alloys in tests to establish salt corrosion resistance in air. In each Figure, the result of Ni₃Al (alloy K) is included for comparison purposes.

5 TABLE 2.

5

Results of Salt Coat Corrosion Test at 900°C (1.5 mg/cm⁻² of Na₂SO₄).

| Test duration in Hours and weight gain in mg/sq.cm. | | | | | |
|---|----------------|----------------|-----------------|-----------------|----|
| 10 Alloys | 24 hrs. | 48 hrs. | 72 hrs. | 96 hrs. | 10 |
| K | 5.1 mg/sq.cm. | 7.3 mg/sq.cm. | 10.5 mg/sq.cm. | 12.3 mg/sq.cm. | |
| G | 32.3 mg/sq.cm. | 70.1 mg/sq.cm. | 104.6 mg/sq.cm. | 128.1 mg/sq.cm. | |
| A. | 4.9 mg/sq.cm. | — | 4.8 mg/sq.cm. | 5.4 mg/sq.cm. | |
| 15 B | 2.7 mg/sq.cm. | 3.2 mg/sq.cm. | 3.5 mg/sq.cm. | 3.8 mg/sq.cm. | 15 |
| R | 4.7 mg/sq.cm. | 11.2 mg/sq.cm. | 22.9 mg/sq.cm. | 41.5 mg/sq.cm. | |
| H | 15.3 mg/sq.cm. | 24.5 mg/sq.cm. | 108 mg/sq.cm. | 111 mg/sq.cm. | |
| 20 S | 1.0 mg/sq.cm. | 3.7 mg/sq.cm. | 2.5 mg/sq.cm. | 5.0 mg/sq.cm. | 20 |
| J | 13 mg/sq.cm. | 23.5 mg/sq.cm. | 23.5 mg/sq.cm. | 23.9 mg/sq.cm. | |
| W | 2.7 mg/sq.cm. | 4.3 mg/sq.cm. | 6.5 mg/sq.cm. | 7.8 mg/sq.cm. | |
| L | 16.0 mg/sq.cm. | 28 mg/sq.cm. | 29.5 mg/sq.cm. | 30.3 mg/sq.cm. | |
| 25 X | 1.0 mg/sq.cm. | 2 mg/sq.cm. | 3.5 mg/sq.cm. | — | 25 |
| N | 28.9 mg/sq.cm. | 75.9 mg/sq.cm. | 117.8 mg/sq.cm. | 123 mg/sq.cm. | |
| Y | 1.0 mg/sq.cm. | 3.7 mg/sq.cm. | 4.1 mg/sq.cm. | 6.6 mg/sq.cm. | |

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The following Table 3 and Fig. 6 show results for total immersion sulphidation resistance tests at 925°C for alloy GP5 vs alloy GP4 and Fig. 7 shows results for cyclic oxidation resistance in respect of two alloys according to the invention vs a commercially-available superalloy.

In the cyclic oxidation resistance tests each cycle consisted of heating the alloy up to 1100°C and holding it at this temperature for total time of 40 minutes and thereafter cooling the alloy to 20°C and holding it at this temperature for a total of 20 minutes.

In Fig. 7 alloy MARM is a commercially available alloy included for purposes of comparison and consists of chromium 9%, cobalt 10%, tungsten 12%, niobium 1%, aluminium 5%, titanium 2%, carbon 0.15%, boron 0.015%, zirconium 0.05% and balance nickel.

40

40

TABLE 3.

Total Immersion Sulphidation Test at 925°C in 10% NaCl and Na₂SO₄.

| Test Duration in Hours and Descaled weight loss per unit area (mg.cm ⁻²). | | | | | 45 |
|---|-----------------------------|-----------------------------|----------------------------|--|----|
| | 1 hour. | 4 hours. | 15 hours. | | |
| 45 GP4 | 149.1 mg/cm ⁻² . | 430.7 mg/cm ⁻² . | Totally attacked | | |
| 50 GP5 | 9.4 mg/cm ⁻² . | 40.1 mg/cm ⁻² . | 8.09 mg/cm ⁻² . | | 50 |

CLAIMS

1. A nickel and chromium-based alloy consisting, in percentages by weight and apart from impurities, of aluminium (4 to 13.5%), chromium (trace to 6%), one or more metals of the platinum group (trace to 20% total) and balance nickel.

2. An alloy according to claim 1 including one or more of the metals hafnium (trace to 5%), titanium (trace to 6%) and tantalum (trace to 12%).

3. An alloy according to claim 1 or claim 2 containing from a trace to the weight specified of one or more of the following metals:

| | | | |
|----|-----------------------|-------|----|
| | niobium | 6% | |
| | carbon | 0.15% | |
| | boron | 0.1% | |
| 5 | cobalt | 10% | 5 |
| | molybdenum | 14% | |
| | tungsten | 14% | |
| | zirconium | 1.75% | |
| | scandium, yttrium or | | |
| 10 | oxides thereof and/or | | 10 |
| | rare earth metals | | |
| | or oxides | 3% | |
| | silicon | 0.25% | |
| | magnesium | 1% | |
| 15 | iron | 10% | 15 |
| | manganese | 0.25% | |
| | vanadium | 2% | |

4. An alloy according to claim 3 wherein scandium, yttrium and the rare earth metals are at least partially present in the form of their respective oxides. 20

5. An alloy according to claim 3 wherein the metals niobium, carbon, boron, cobalt, molybdenum, tungsten, zirconium, silicon, magnesium, iron, manganese and vanadium are at least partially present in the form of their respective oxides.

6. An alloy according to claim 3 consisting of aluminium 7.3%, titanium 0.8%, cobalt 6.5%, niobium 0.99%, molybdenum 1.0%, tantalum 10.5%, chromium 2%, tungsten 2%, carbon 0.05%, boron 0.01%, zirconium 0.07%, platinum 7.5% and balance nickel. 25

7. An alloy substantially as hereinbefore described and with reference to the alloys specified in Table 1.

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